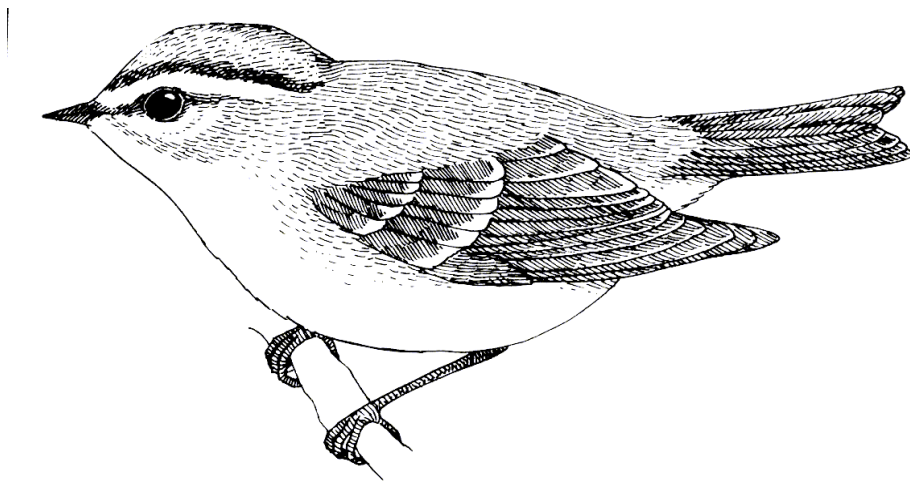**California Wildlife Habitat Relationships Program**
California Department of Fish and Game

HABITAT SUITABILITY MODELS FOR USE WITH ARC/INFO:
GOLDEN-CROWNED KINGLET

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GOLDEN-CROWNED KINGLET

by

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GOLDEN-CROWNED KINGLET (*Regulus satrapa*)

HABITAT USE INFORMATION

General

The golden-crowned kinglet (*Regulus satrapa*) inhabits coniferous forests in western North America (American Ornithologists' Union 1983). In northern California, they are often abundant yearlong residents and breeders in the coastal ranges from the Oregon border to Santa Cruz County and throughout the Cascade and Sierra Nevada ranges. In southern California, they are uncommon, local breeders in the White Mountains and in the Transverse and Peninsular ranges (Zeiner et al. 1990). Habitats utilized during the breeding season in California include moderate to dense mixed-conifer, Douglas-fir (*Pseudotsuga menziesii*), redwood *(Sequoia sempervirens)*, and red fir (*Abies magnifica*) forests. During the winter, many individuals move downslope into valley-foothill hardwood and valley-foothill riparian habitats (Zeiner et al. 1990). Wintering populations in southern California are sparse (Grinnell and Miller 1944; Gaines 1977).

Food

Golden-crowned kinglets are primarily foliage-gleaning insectivores (Zeiner et al. 1990). However, prey may also be taken while hovering or by flycatching (Bent 1949). In Arizona, golden-crowned kinglets foraged by gleaning 87% of the time, by hovering 11%, by hawking 2%, and by pecking in bark 2% (Franzreb 1984). In the Sierra Nevada, golden-crowned kinglets foraged by gleaning approximately 90% of the time, with hovering and lunging (leaping from a stationary position to take insects moving inside the tree crown) representing the other foraging behaviors (Airola and Barrett 1985). Prey items include insects, spiders, other small invertebrates and their eggs, and occasionally seeds, fruits, and sap from woodpecker holes (Zeiner et al. 1990). In the western Sierra Nevada, stomach contents of nine golden-crowned kinglets included 27.5% vegetable material and 72.5% animal matter (Dahlsten et al. 1985).

By using twigs and small branches as foraging perches, golden-crowned kinglets forage high in the outer foliage of conifers and occasionally hardwoods (Grinnell and Storer 1924; Grinnell and Miller 1944). In Arizona, this species selected trees averaging 27 m (89 ft) tall for foraging purposes and utilized small branches and twigs (diameter average 1.3 cm [0.5 in]) 98% of the time as foraging perches (Franzreb 1984). Golden-crowned kinglets in the Sierra Nevada exhibited a preference for foliage heights averaging 20 m (66 ft) for foraging (Airola and Barrett 1985), while kinglets in Arizona foraged at a mean height of 10 m (34 ft) (Franzreb 1984). In Arizona, Engelmann spruce (*Picea engelmannii*), blue spruce (*P. pungens*), and Douglas-fir were preferred by golden-crowned kinglets (Franzreb 1984), while golden-crowned kinglets in the Sierra Nevada preferred white fir (*Abies concolor*) and sugar pine *(Pinus lambertiana)* (Airola and Barrett 1985). Golden-crowned kinglets utilized incense cedar (*Calocedrus decurrens*) for foraging purposes to a greater extent during the winter than they did in the summer (Morrison et al. 1985, 1989).

Water

No water requirements have been documented for this species.

Cover

Golden-crowned kinglets find suitable cover in moderate to dense coniferous or broad-leaved forests, which are habitat conditions similar to their food and reproductive requirements (Grinnell and Storer 1924; Grinnell and Miller 1944; Bent 1949; Zeiner et al. 1990). In the Sierra Nevada, golden-crowned kinglets showed a preference for closed canopies at all times of the year (Beedy 1981). This trend was slightly more pronounced in mixed-conifer forests than in red fir forests. Golden-crowned kinglets are gradually expanding their range by colonizing spruce (*Picea* spp.) plantations (Petersen 1988). Cover requirements are further described under the Food and Reproduction sections of this document.

Reproduction

Golden-crowned kinglet females begin building nests in mid-May in Yosemite (Grinnell and Storer 1924). In southern latitudes, breeding begins in early April, while breeding in northern latituds begins in early June. Nests are concealed in foliage at the tips of branches or in clusters of live, hanging twigs. Nest height generally varies from 1.5-15 m (5-50 ft) above ground, but it may be higher (Bent 1949; Zeiner et al. 1990). Parasitism of golden-crowned kinglet nests by brown-headed cowbirds *(Molothrus ater)* has been reported (Verner and Ritter 1983).

Interspersion and Composition

Golden-crowned kinglets are found in small flocks from the time the broods appear in early summer until the beginning of the next nesting season (Grinnell and Storer 1924). They are often found as single-species flocks but may also flock with other species. During the winter in Marin County, golden-crowned kinglets are often seen flocking with ruby-crowned kinglets (*R. calendula*), chestnut-backed chickadees (*Parus rufescens*), Hutton's vireos (*Vireo huttoni*), Townsend's warblers (*Dendroica townsendi*), and brown creepers (*Certhia americana*) (I. Timossi, pers. comm.). In the Sierra Nevada, Morrison et al. (1987) found golden-crowned kinglets flocking primarily with chestnut-backed chickadees and red-breasted nuthatches (*Sitta canadensis*); they foraged less often with mountain chickadees *(Parus gambeli)*, brown creepers, dark-eyed juncos (*Junco hyemalis*), and ruby crowned kinglets. Yellow-rumped warblers *(Dendroica coronata)*, robins (*Turdus migratorius*) and white-headed woodpeckers (*Picoides albolarvatus*) are occasional foraging partners.

In the Sierra Nevada, density estimates of nesting golden-crowned kinglets ranged from a low of 14 birds/40 ha (100 ac) in open-canopy, mixed-conifer forest to a high of 66 birds/40 ha (100 ac) in closed-canopy, red fir forest (Beedy 1981). Bock and Lynch (1970) found 17.6 pairs/40 ha (100 ac) of golden-crowned kinglets in a mixed coniferous forest on the eastside of the Sierra Nevada. Summer densities of golden-crowned kinglets in Arizona varied over two years from 26.3 to 30.8 birds/40 ha (100 ac) (Franzreb and Ohmart 1978), while Carothers et al. (1973) found 17 pairs/40 ha (100 ac) in spruce-fir forests in Arizona. In Minnesota, territories averaged 1.6 ha (4 ac) and ranged from 0.9-2.5 ha (2.2-6.2 ac) (Galati and Galati 1985). Territorial

defense was performed primarily through song by the male.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area.

The California Wildlife Habitat Relationships (CWHR) System (Airola 1988; Mayer and Laudenslayer 1988; Zeiner et al. 1990) contains habitat ratings for each habitat type predicted to be occupied by golden-crowned kinglets in California.

Season.

This model is designed to predict the suitability of habitat for golden-crowned kinglets throughout the year. Model predictions, however, may be more accurate during the breeding season.

Cover types.

This model can be used anywhere in California for which an ARC/INFO map of CWHR habitat types exists. The CWHR System contains suitability ratings for reproduction, cover, and feeding for all habitats golden-crowned kinglets occupy. These ratings can be used in conjunction with the ARC/INFO habitat map to model wildlife habitat suitability.

Minimum habitat area.

Minimum habitat area is defined as the minimum amount of contiguous habitat required before a species will occupy an area. Specific information on minimum areas required for golden-crowned kinglets was not found in the literature. This model assumes two home ranges is the minimum area required to support a golden-crowned kinglet population during the breeding season.

Verification level.

The spatial model presented here has not been verified in the field. The CWHR suitability values used are based on a combination of literature searches and expert opinion. We strongly encourage field testing of both the CWHR database and this spatial model.

Model Description

Overview.

This model uses CWHR habitat type as the main factor determining suitability of an area for this species.

A CWHR habitat type map must be constructed in ARC/INFO GRID format as a basis for the model. The GRID module of ARC/INFO was used because of its superior functionality for spatial modeling. Only crude spatial modeling is possible in the vector portion of the ARC/INFO program, and much of the modeling done here would have been impossible without the abilities of the GRID module. In addition to more sophisticated modeling, the GRID module's execution speed is very rapid, allowing a complex model to run in less than 30 minutes.

The following sections document the logic and assumptions used to interpret habitat suitability.

Cover component.

A CWHR habitat map must be constructed. The mapped data (coverage) must be in ARC/INFO GRID format. A grid is a GIS coverage composed of a matrix of information. When the grid coverage is created, the size of the grid cell should be determined based on the resolution of the habitat data and the home range size of the species with the smallest home range in the study. You must be able to map the home range of the smallest species with reasonable accuracy. However, if the cell size becomes too small, data processing time can increase considerably. We recommend a grid cell size of 30 m (98 ft). Each grid cell can be assigned attributes. The initial map must have an attribute identifying the CWHR habitat type of each grid cell. A CWHR suitability value is assigned to each grid cell in the coverage based on its habitat type. Each CWHR habitat is rated as high, medium, low, or unsuitable for each of three life requisites: reproduction; feeding; and cover. The geometric mean value of the three suitability values was used to determine the base value of each cell for this analysis.

Distance to water.

No water requirement was found for this species.

Species' distribution.

The study area must be manually compared to the range maps in the CWHR Species Notes (Zeiner et al. 1990) to ensure that it is within the species' range. All grid cells outside the species' range have a suitability of zero.

Spatial analysis.

Ideally a spatial model of distribution should operate on coverages containing habitat element information of primary importance to a species. For example, in the case of woodpeckers, the size and density of snags as well as the vegetation type would be of great importance. For many small rodents, the amount and size of dead and down woody material would be important. Unfortunately, the large cost involved in collecting microhabitat (habitat element) information and keeping it current makes it likely that geographic information system (GIS) coverages showing such information will be unavailable for extensive areas into the foreseeable future.

The model described here makes use of readily available information such as CWHR habitat type, elevation, slope, aspect, roads, rivers, streams and lakes. The goal of the model is to eliminate areas that are unlikely to be utilized by the species and lessen the value of marginally suitable areas. It does not attempt to address all the microhabitat issues discussed above, nor does it account for other environmental factors such as toxins, competitors, or predators. If and when such information becomes available, this model could be modified to make use of it.

In conclusion, field surveys will likely discover that the species is not as widespread or abundant as predictions by this model suggest. The model predicts potentially available habitat. There are a variety of reasons why the habitat may not be utilized.

Definitions.

Home Range: the area regularly used for all life activities by an individual during the season(s) for which this model is applicable.

Dispersal Distance: the distance an individual will disperse to establish a new home range. In this model it is used to determine if Potential Colony Habitat will be utilized.

Day to Day Distance: the distance an individual is willing to travel on a daily or semi-daily basis to utilize a distant resource (Potential Day to Day Habitat). The distance used in the model is the home range radius. This is determined by calculating the radius of a circle with an area of one home range.

Core Habitat: a contiguous area of habitat of medium or high quality that has an area greater than two home ranges in size. This habitat is in continuous use by the species. The species is successful enough in this habitat to produce offspring that may disperse from this area to the Colony Habitat and Other Habitat.

Potential Colony Habitat: a contiguous area of habitat of medium or high quality that has an area between one and two home ranges in size. It is not necessarily used continuously by the species. The distance from a core area will affect how often Potential Colony Habitat is utilized.

Colony Habitat: Potential Colony Habitat that is within the dispersal distance of the species. These areas receive their full original value unless they are further than three home range radii from a core area. These distant areas receive a value of low since there is a low probability that they will be utilized regularly.

Potential Day to Day Habitat: an area of high or medium quality habitat less than one home range in size, or habitat of low quality of any size. This piece of habitat alone is too small or of inadequate quality to be Core Habitat.

Day to Day Habitat: Potential Day to Day Habitat that is close enough to Core or Colony Habitat can be utilized by individuals moving out from those areas on a day to day basis. The grid cell must be within Day to Day Distance of Core or Colony Habitat.

Other Habitat: contiguous areas of low value habitat larger than two home ranges in size, including small areas of high and medium quality habitat that may be imbedded in them, are included as usable habitat by the species. Such areas may act as "sinks" because long-term reproduction may not match mortality.

The table below indicates the specific distances and areas assumed by this model.

Distance variables:	Meters	Feet
Dispersal Distance	2,110	6,923
Day to Day Distance/ Home Range radius	88	288

Area variables:	Hectares	M^2	Acres	Ft^2
Home Range	2.43	24,282	6	261,360
Core Habitat	4.86	48,364	12	521,720

Application of the Model

A copy of the ARC/INFO AML can be found in Appendix 1. The steps carried out by the macro are as follows:

1.   **Determine Core Habitat**: this is done by first converting all medium quality habitat to high quality habitat and removing all low value habitat, and contiguous areas of habitat are grouped into regions. The area of each of the   regions is determined. Those large enough (two home ranges) are   maintained in the Core Habitat coverage. If no Core Habitat is identified then   the model will indicate no suitable habitat in the study area.

2.   **Identify Potential Colony Habitat**: using the coverage from Step 1, determine which regions are one to two home ranges in size. These are

Potential Colonies.

3. **Identify Potential Day Use Habitat**: using the coverage derived in Step 1, determine which areas qualify as Potential Day to Day Habitat.

4. **Calculate the Cost Grid**: since it is presumed to be more difficult for animals to travel through unsuitable habitat than suitable habitat we use a cost grid to limit travel based on habitat suitability. The cost to travel is one for high or medium quality habitat. This means that to travel 1 m through this habitat costs 1 m of Dispersal Distance. The cost to travel through low quality habitat is two and unsuitable habitat costs four. This means that to travel 1 m through unsuitable habitat costs the species 4 m of Dispersal Distance.

5. **Calculate the Cost Distance Grid**: a cost distance grid containing the minimum cost to travel from each grid cell to the closest Core Habitat is then calculated using the Cost Grid (Step 4) and the Core Habitat (Step 1).

6. **Identify Colony Habitat**: based on the Cost Distance Grid (Step 5), only Potential Colony Habitat within the Dispersal Distance of the species to Core Habitat is retained. Colonies are close enough if **any** cell in the Colony is within the Dispersal Distance from Core Habitat. The suitability of any Colony located further than three home range radii from a Core Habitat is changed to low since it is unlikely it will be utilized regularly.

7. **Create the Core + Colony Grid**: combine the Core Habitat (Step 1) and the Colony Habitat (Step 6) and calculate the cost to travel from any cell to Core or Colony Habitat. This is used to determine which Potential Day to Day Habitat could be utilized.

8. **Identify Day to Day Habitat**: grid cells of Day to Day Habitat are only accessible to the species if they are within one half of a home range radius from the edge of the nearest Core or Colony Habitat. Add these areas to the Core + Colony Grid (Step 7).

9. **Add Other Habitat**: large areas (two home ranges in size) of low value habitat, possibly with small areas of high and medium habitat imbedded in them may be utilized, although marginally. Add these areas back into the Core + Colony + Day to Day Grid (Step 8), if any exist, to create the grid showing areas that will potentially be utilized by the species. Each grid cell contains a one if it is utilized and a zero if it is not.

10. **Restore Values**: all areas that have been retained as having positive habitat value receive their original geometric mean value from the original geometric value grid (see *Cover component* section) with the exception of distant colonies. Distant colonies (colonies more than three home range radii distant) have their value

reduced to low because of the low likelihood of utilization.

Problems with the Approach

Cost.

The cost to travel across low suitability and unsuitable habitat is not known. It is likely that it is quite different for different species. This model incorporates a reasonable guess for the cost of movement. A small bird will cross unsuitable habitat much more easily than a small mammal. To some extent differences in vagility between species is accounted for by different estimates of dispersal distances.

Dispersal distance.

The distance animals are willing to disperse from their nest or den site is not well understood. We have used distances from studies of the species or similar species when possible, otherwise first approximations are used. More research is urgently needed on wildlife dispersal.

Day to day distance.

The distance animals are willing to travel on a day to day basis to use distant resources has not been quantified for most species. This issue is less of a concern than dispersal distance since the possible distances are much more limited, especially with small mammals, reptiles, and amphibians. Home range size is assumed to be correlated with this coefficient.

SOURCES OF OTHER MODELS

No other habitat models were found for the golden-crowned kinglet.

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APPENDIX 1: Golden-Crowned Kinglet Macro

```
/*        GOLDEN-CROWNED KINGLET

/* gkimodel.aml - This macro creates an HSI coverage for the
/*         Golden-crowned Kinglet.

/* Version:  Arc/Info 6.1 (Unix), GRID-based model.

/* Authors:  Irene Timossi, Sarah Miller, Wilde Legard,
/*        and Reginald H. Barrett
/*        Department of Forestry & Resource Management
/*        University of California, Berkeley

/* Revision: 2/10/95

/* --------------------------------------------------------------

/* convert .ID to uppercase for info manipulations

&setvar .ID [translate %.ID%]

/* Start Grid

grid

/*

&type (1)  Initializing Constants...

/*   Homerange: the size of the species' homerange.

/*   DayPay: The amount the species is willing to pay traveling on
/*   a day-to-day basis.  Used to determine the area utilized on a
/*   day-to-day basis.

/*   DispersePay: Distance traveled when dispersing.  The amount
/*   the animal is willing to pay when dispersing from a core area.

/*   High:  The value in the WHR grid which indicates high quality habitat.

/*   Medium:  The value in the WHR grid which indicates medium quality habitat.

/*   Low:  The value in the WHR grid which indicates low quality habitat.

/*   None:  The value in the WHR grid which indicates habitat of no value.

/*   SpecCode: The WHR code for the species

/*   AcreCalc:  The number needed to convert square units
/*         (feet or meters) to acres.


&setvar SpecCode = B375

&if %.Measure% = Meters &then
  &do
    &setvar Homerange     = 24282
    &setvar DayPay        = 88
    &setvar DispersePay   = 2110
```

```
      &setvar AcreCalc      = 4047
    &end
  &else
    &if %.Measure% = Feet  &then
      &do
        &setvar Homerange     = 261360
        &setvar DayPay       = 288
        &setvar DispersePay   = 6923
        &setvar AcreCalc     = 43560
      &end
    &else
      &do
        &type Measurement type incorrect, check spelling.
        &type Only Meters and Feet are correct.
        &goto &BADEND
      &end

  &setvar High        = 3
  &setvar Medium      = 2
  &setvar Low         = 1
  &setvar None        = 0
```

/*   The following global variables are declared in the menu:

/*   .WHRgrid (WHR grid name): the name of the grid containing all
/*   the WHR information.

/*   .Bound (Boundary grid name): the grid containing only the
/*   boundary of the coverage. All cells inside the boundary
/*   have a value of 1. All cells outside the boundary must
/*   have a value < 1.

/*   .ID (Identifier): a 1 to 4 character code used to identify
/*   the files produced by this program. You may prefer
/*   to use an abbreviation of the species' common name
/*   (e.g. use `fis1` for fisher).

/*   .SizeOfCell (Cell size): the size (width) of the cells
/*   used in the coverage grids. All grids used in the
/*   analysis must have the same cell size.

/*   .Measure: the units the coverage is measured in (feet or meters).

&type (2) Creating working grid of geometric means...

/*   Create a Geometric Means grid (Geom) for the species by
/*   copying these values from the WHR grid.

Geom = %.WHRgrid%.%SpecCode%_G

/*

&type (3) Changing %Medium% value cells to %High% value for Merge grid...

/*   Create a grid (Merge) merging Medium and High
/*   value cells from the Geometric mean grid (Geom),
/*   while leaving the value of other cells (Low and None) unchanged.
/*   Merge by changing the value of all medium cells to High.

Merge = con(Geom == %Medium%,%High%,Geom)

```
/*

&type (4)  Converting Merge grid zones into a Region grid...

/*    Convert the zones of the merge grid (Merge) into
/*    unique regions (Region). These will be used later
/*    to create core, colony, and day-to-day areas.

Region = regiongroup(Merge,#,EIGHT)

/*

&type (5)  Calculating the area of Region grid zones...

/*    Calculate the area of the zones (ZoneArea) on the region
/*    grid (Region).

ZoneArea = zonalarea(Region)

/*

&type (6)  Creating a Core Area grid...

/*    Extract areas from the zonal area grid (ZoneArea)
/*    suitable for core areas (Core). Core areas are defined
/*    as the Medium+High zones in the merge grid (Merge)
/*    with an area of at least two home ranges (%Homerange%).
/*    Set their value = 1.

if (Merge == %High% and ZoneArea >= %Homerange% * 2)
  Core = 1
endif

&if not [exists Core -vat] &then
  &goto END

/*

&type (7)  Creating a Colony grid...

/*    Extract areas from the zonal area grid (zoneArea)
/*    possibly suitable for colonization (ColTemp).
/*    Colony areas are defined as Low or Medium+High zones
/*    in the Merge grid (Merge) with an area of between one
/*    and two home ranges (%Homerange%). Set their value = 1.

/*    Then set all nodata values in the grid to zero (Colony).

docell
  if (Merge == %High%)
    if (ZoneArea > %Homerange% and ZoneArea < %Homerange% * 2)
      ColTemp = 1
    endif
  endif
end

Colony = con(isnull(ColTemp),0,ColTemp)

/*

&type (8)  Creating a Day-to-Day Use grid...
```

```
/*    Create a grid based on the values in the zonal
/*    area grid (ZoneArea) and merge grid (Merge)
/*    suitable for day-to-day use (DayToDay). Day-to-day use
/*    areas are defined as Low if the area is less than two
/*    homeranges in size or Medium+High zones in the
/*    merge grid (Merge) with an area of less than one home
/*    range (%Homerange%). Set their value = 1.

if ((Merge > %Low% and ZoneArea <= %Homerange%) or ~
   (Merge == %Low% and ZoneArea < %Homerange% * 2))
  DayToDay = 1
else
  DayToDay = 0
endif

/*

&type (9)  Creating a Cost Grid based on habitat value...

/*    Using the merge grid (Merge), create a cost grid (Cost)
/*    based on the habitat-value. Cost represents the relative
/*    resistance a species has to moving across different quality
/*    habitat:  Habitat-value   Cost
/*             None          4
/*             Low           2
/*             Medium+High    1

if (Merge == %None%)
  Cost = 4
else if (Merge == %Low%)
  Cost = 2
else if (merge == %High%)
  Cost = 1
endif

/*

&type (10) Calculating cost to travel from Core Areas...

/*    Calculate the cost to travel the distance (CostDist)
/*    from the nearest core area source (Core) using the cost
/*    grid (Cost).
/*

CostDist = CostDistance(Core,Cost)

/*

&type (11) Calculating which Colony areas are Cost Effective...

/*    If Colony Areas exist...
/*    Find the areas in the Colony grid (Colony) that could
/*    be colonized from the core areas:

/*    Assign costs to all cells in the Colony areas (Colony)
/*    from the Cost grid (CostDist). Zero surrounding NODATA areas.

/*    Make each colony a separate zone (ZoneReg) using
/*    the regiongroup command.
```

```
/*    Use zonalmin to find the minimum cost to arrive at each
/*    colony (ZoneMin).

/*    Set all NODATA cells to zero in ZoneMin to produce
/*    ColZer1.

/*    To find out which of the potential colonies can be utilized,
/*    determine which have a cost that is equal to or less than
/*    DispersePay. If the cost to get to a colony is less than
/*    or equal to DispersePay, keep it in grid Col.

/*    Fill the null value areas in Col with zeros to create ColZer2


&if not [exists ColTemp -vat] &then
  &goto SkipColony

ColDist = con(Colony > 0,CostDist,0)
ZoneReg = regiongroup(Colony,#,EIGHT)
ZoneMin = zonalmin(ZoneReg,ColDist)
ColZer1 = con(isnull(ZoneMin),0,ZoneMin)

if (ColZer1 <= %DispersePay% and ColZer1 > 0)
  Col = Colony
else
  Col = Core
endif

ColZer2 = con(isnull(Col),0,Col)

/*

&type (12)  Creating Core + Colony grid...

/*    If colonies exist....
/*    Create a grid (ColCore) that combines the core
/*    (Core) and colony (Colony) grids.
/*    This grid will be used to analyze day-to-day use.


if (Colony == 1)
  ColCore = 1
else
  ColCore = Core
endif

&label SkipColony


&type (13)  Calculate cost to travel from Core and Colony Areas...

/*    If colonies exist...
/*    Calculate the cost to travel the distance (CostDis2)
/*    from the nearest core or colony area source (ColCore).
/*    Otherwise just copy the CostDist grid to use for Day-to-Day
/*    analysis.

&if not [exists ColTemp -vat] &then
  CostDis2 = CostDist
&else CostDis2 = CostDistance(ColCore,Cost)
```

```
/*

&type (14) Calculating which Day-to-Day areas are Cost Effective...

/*    This step adds the utilized Day-to-Day cells to the
/*    Core + Colony Area grid (ColZer2) to produce the
/*    Day1 grid.

/*    Use the Core + Colony Cost grid (CostDis2)to find out
/*    what can actually be used day-to-day (any cell with
/*    a cost of DayPay or less).

/*    Retain any cell in the Day-to-Day grid (DayToDay) with
/*    a cost less than or equal to DayPay and greater than zero.

/*    If the Distance-Cost grid (CostDis2) = 0,
/*    it is part of the Core or Colony Area and
/*    should gets its value from Core + Colony Area
/*    grid (ColZer2).

&if [exists ColTemp -vat] &then
  &do
    if (CostDis2 <= %DayPay% and CostDis2 > 0)
      Day1 = DayToDay
    else
      Day1 = ColZer2
    endif
  &end
&else
  &do
    if (CostDis2 <= %DayPay% and CostDis2 > 0)
      Day1 = DayToDay
    else
      Day1 = Core
    endif
  &end

/*

&type (15)  Finding Other Areas That May Be Utilized....

/*    This step picks up any large low value areas and any small
/*    medium or high value polygons that are imbeded
/*    in them.

/*    First find any areas that are not currently in the included
/*    set (Day1Z) but are in the original geometric mean coverage (geom)
/*    set Other to 1 where Day1Z = 0.

/*    if Other is all nodata, create the All coverage from
/*    the Day1Z coverage.

/*    Split all other areas into separate regions (OthReg)

/*    Calculate the area of the regions (OthArea).

/*    Keep any region in OthArea with an area > 2 homeranges (Util).

/*    Change any null values in Util to zeros (OthZero).

/*    Add these areas to the Day1 coverage to create All
```

```
Day1Z = con(isnull(Day1),0,Day1)

if ((Day1Z < 1) and (Geom > 0))
  Other = 1
endif

&if not [exists Other -vat] &then
  All = Day1Z
&else
  &do
    OthReg = regiongroup(other,#,EIGHT)

    OthArea  = zonalarea(OthReg)

    if (OthArea >= %Homerange% * 2)
      Util = 1
    else
      Util = 0
    endif

    OthZero = con(isnull(Util),0,Util)

    if (OthZero == 1)
      All = OthZero
    else
      All = Day1Z
    endif
  &end

/*

&type (16) Creating a Value grid...

/*     For any cell in All that has a value of 1, store the suitability
/*     value from the Geometric mean grid (Geom) to the Value grid.

/*     Other cells inside the boundary (%.Bound%) get a value of 0.

/*

if (All == 1)
  Value = Geom
else if (%.Bound% == 1)
  Value = 0
endif

/*

&type (17)  Creating an HSI grid...

/*     if Colonies exist....
/*     For any cell that was part of a colony that is further than
/*     3 times the HR radius (DayPay) away from a core area, set the suitability
/*     to Low.  Distant colonies lose value because of their small size.
/*     This step produces grid Collow.

/*     Set all NODATA values in Collow to zero in ColZer3.

/*     Find any day-to-day use areas (DayToDay) that are being
/*     utilized (ColZer3).  If they are further than four homeranges
/*     from a core area (CostDist), they are utilized from a distant
```

```
/*    colony and their value will be decreased to Low in Day2.


/*    Then change nulls to zero in ValZero

/*    Keep all data within the boundary; call this final grid HSI.

&if [exists ColTemp -vat] &then
  &do
    if (ColZer1 >= %DayPay% * 3)
      Collow = %Low%
    else
      Collow = Value
    endif

    ColZer3 = con(isnull(Collow),0,Collow)

    if ((CostDist > %DayPay% * 4) and (ColZer3 > 0) and ~
      (DayToDay == 1))
      Day2 = 1
    else
      Day2 = ColZer3
    endif
  &end
&else
    Day2 = Value

valzero = con(isnull(Day2),0,Day2)

if (%.Bound% == 1)
  %.ID%hsi = valzero
endif

/*

&type (18)  Quiting from GRID and adding the acres field.....

/*    Quit from GRID (Q), then run additem to add an acre item to
/*    the HSI grid vat file (%ID%HSI.vat). Reindex on value when done.

Q
additem %.ID%hsi.vat %.ID%hsi.vat acres 10 10 i
indexitem %.ID%hsi.vat value

/*

&type (19)  Calculating acres.....

/*    Use INFO to calculate the acreage field: Multiply the number
/*    of cells by the cell size squared and divide by the number of
/*    square meters per acre (4047). Reindex on value when done.

&data arc info
arc
select %.ID%hsi.VAT
CALC ACRES = ( COUNT * %.SizeOfCell% * %.SizeOfCell% ) / %AcreCalc%
Q STOP

&END

indexitem %.ID%hsi.vat value
```

```
/*

&type  (20) Killing all intermediate coverages before ending macro...

/* &goto OKEND

grid

kill Geom
kill Merge
kill Region
kill ZoneArea
kill Core
kill ColTemp
kill Colony
kill DayToDay
kill Cost
kill CostDist
kill ColDist
kill ZoneReg
kill ZoneMin
kill ColZer1
kill Col
kill ColZer2
kill ColCore
kill CostDis2
kill Day1
kill Day1Z
kill Other
kill OthReg
kill OthArea
kill Util
kill OthZero
kill All
kill Value
kill Collow
kill ColZer3
kill Day2
kill valzero

q

&goto OKEND

&label END
&type **
&type **
&type NO CORE AREAS EXIST, EXITING MACRO
&type **
&type **

kill Core
kill Region
kill ZoneArea
kill Merge
kill Geom

quit

&label OKEND
&label BADEND
```

&type -–----------- All done! ---–----------

&return